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Differential Geometry Based Model for Eddy Current Inspection of U-Bend Sections in Steam Generator Tubes

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A numerical finite element model, capable of simulating eddy current testing (ECT) of steam generator (SG) tubing in power plants is an ongoing project at MSU. The simulation model software SGTSIM models the free span and tube support regions of the tube with a variety of commercial probes, such as bobbin, pancake, +Point and array probes. The simulation model predicts defect signals which have been validated by experimental ECT data.

The modeling of U-Bend segment in steam generator tubes for predicting eddy current probe signals from cracks, wear and pitting in this region poses challenges and is non-trivial. Meshing the geometry in the Cartesian coordinate system will require a large number of elements to model the U-bend region. Also, since the lift-off distance between the probe and tube wall is usually very small, a very fine mesh is required near the lift-off region to accurately describe the eddy current field.

This paper presents a U-bend model using differential geometry principles that exploit the result that Maxwell's equations are covariant with respect to changes of coordinates and independent of metrics [1-2]. The equations remain unaltered in their form, regardless of the choice of the co-ordinate system, provided the electric and magnetic field quantities are represented in the proper tensor densities (contravariant or covariant components) [3-4].

The complex shapes are mapped into simple straight sections, while small lift-off is mapped to larger values, as shown in Fig. 1, thus reducing the intrinsic dimension of the mesh and stiffness matrix.

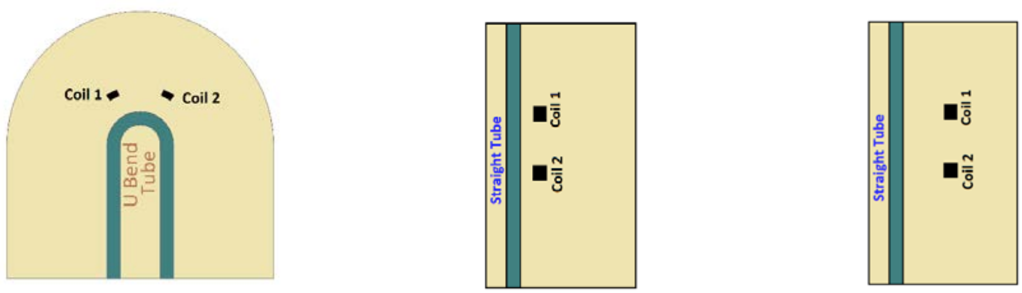

Figure 1. Geometry of the U-bend tube in the Cartesian frame (left) and the same problem after a proper change of (spatial) variables (middle) and with increased lift-off (right).

In this contribution, the numerical implementation of the above approach will be discussed with regard to field and current distributions within the U-bend tube wall. The approach is evaluated in terms of efficiency and accuracy by comparing the results with that obtained using a conventional FE model in Cartesian coordinates.

References:

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